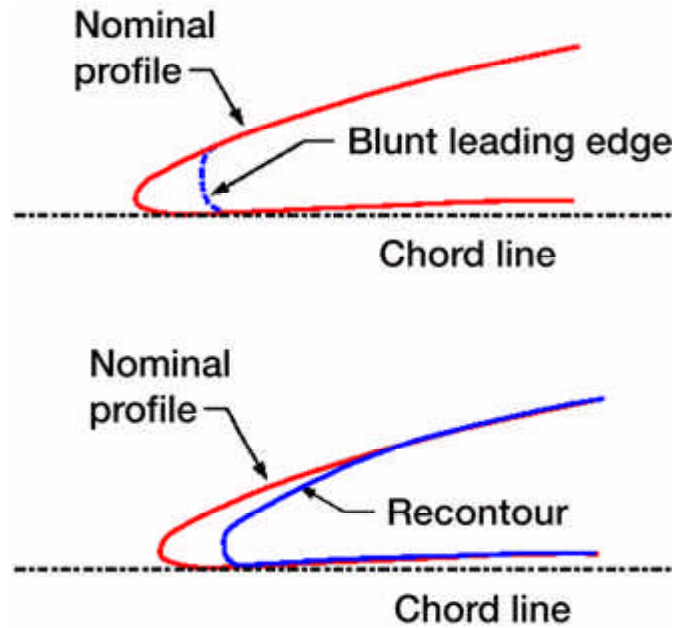


Effect of Variable Chord Length on Transonic Axial Rotor Performance Investigated

During the life of any gas turbine, blade erosion is present, especially for those units that are exposed to unfiltered air, such as aviation turbofan engines. The effect of this erosion is to reduce the blade chord progressively from the midspan to the tip region and to roughen and distort the blade surface. The effects of roughness on rotor performance have been documented by Suder et al. (ref. 1) and Roberts (ref. 2). These papers indicate that the penalty for leading-edge roughness and erosion can be significant. Turbofan operators, therefore, restore chord length at routine maintenance intervals to regain performance before deterioration is too severe to salvage blades. As the rotor blades erode, the leading edge becomes rough--blunt and distorted from the nominal shape--and the aerodynamic performance suffers. Nominal performance can be recovered by recontouring the leading edges as illustrated in the figure to the right. This process, which inherently shortens the blade chord, can be used until the blade chord erodes to the stall limit. Below this chord length, which varies among engine-compressor types, a decrease of stall margin is likely.

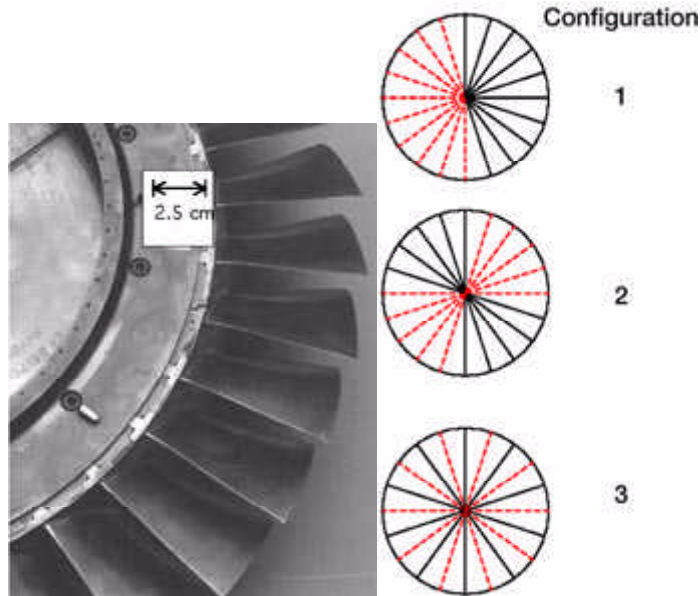
After compressor blade rework that includes leading edge recontouring, the blades have different chord lengths, ranging from blades that are near nominal chord length down to those near the stall chord limit. Furthermore, as blades erode below the stall limit, they must be replaced with new blades that have the full nominal chord length. Consequently, a set of compressor blades with varying chord lengths will be installed into each turbofan engine that goes through a complete maintenance cycle. The question arises, "Does fan or compressor performance depend on the order in which mixed-chord blades are installed into a fan or compressor disk?"



Blade leading edge. Top: Leading edge blunt because of erosion. Bottom: Recontoured leading edge.

To investigate this issue, the aerodynamic performance of a NASA transonic compressor rotor (shown in the photograph) operating with blades of varying chord length was measured in back-to-back compressor tests in NASA Glenn Research Center's W8 Transonic Compressor Facility. One half of the rotor blades were the full nominal chord length, and the remaining half of the blades were cut back at the leading edge to 95 percent of the chord length and recontoured. The rotor aerodynamic performance was measured at 100, 80, and 60 percent of the design speed for the blade installation configurations shown in the figure to the right: (1) nominal-chord blades in half of the disk and short-chord blades in half of the disk, (2) four alternating quadrants of nominal-chord and short-chord blades, and (3) nominal-chord and short-chord blades alternating around the disk.

The test results indicate only slight differences in performance with the "alternating" blade installation configuration at specific operating conditions, which are documented and discussed further in reference 3. Otherwise, there was no significant difference in performance among the various blade configurations. Since the three installation configurations tested cover the extremes of possible chord mismatch, it can be concluded that chord mismatching is not important to aerodynamic performance above the stall chord limit, which for most civil aviation engines is between 94 and 96 percent of nominal (new) chord length. This statement applies *only* to blades that have been refurbished with a leading edge recontour.



Left: Transonic compressor for NASA rotor35. Right: Tested blade configurations. (1) All long-chord blades grouped together; all short-chord blades grouped together. (2) Alternating quadrants of long- and short-chord blades. (3) Long- and short-chord blades alternating around the wheel.

Bibliography

Suder, K.L., et al.: The Effect of Adding Roughness and Thickness to a Transonic Axial Compressor Rotor. ASME J. Turbomachinery, vol. 117, 1994, pp. 491-505.

Roberts, W.B.: Advanced Turbofan Blade Refurbishment Technique. ASME J. Turbomachinery, vol. 117, no. 4, 1995, pp. 666-667.

Roberts, W.B., et al.: The Effect of Variable Chord Length on Axial Transonic Axial Rotor Performance. ASME Paper 2002-GT-0498, 2002. To be published in the ASME J. Turbomachinery, 2002.

Glenn contacts: Dr. Kenneth L. Suder, 216-433-5899, Kenneth.L.Suder@grc.nasa.gov; Dr. Anthony J. Strazisar, 216-433-5881, Anthony.J.Strazisar@grc.nasa.gov; and Scott A. Thorp, 216-433-8013, Scott.A.Thorp@grc.nasa.gov

Author: Kenneth L. Suder

Headquarters program office: OAT

Programs/Projects: UEET